

LA-UR--87-3210

DE88 000486

TITLE THE RATIONALE FOR THE DESIGN OF CPRF/ZTH,
THE NEXT STEP IN THE U.S. RFP PROGRAM

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SUBMITTED TO: INTERNATIONAL SCHOOL OF PLASMA PHYSICS
WORKSHOP ON PHYSICS OF MIRRORS, REVERSED
FIELD PINCHES AND COMPACT TORI
VARENNA, ITALY, SEPTEMBER 1-11, 1987

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THE RATIONALE FOR THE DESIGN OF CPRF/ZTH, THE NEXT

STEP IN THE U.S. RFP PROGRAM

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The U.S. magnetic fusion program is now embarked on the construction of a Confinement Physics Research Facility (CPRF) located at the Los Alamos National Laboratory. The first experiment to be tested in the CPRF is a 4 MA air core reversed field pinch (RFP) device called ZTH. This is the next major step in the U.S. RFP program. The performance expectations of the CPRF/ZTH at the 4 MA current level are:

- a. Ion and electron temperature: $T_i \sim T_e \sim 4 \text{ keV}$
- b. Plasma density: $n_e \sim 10^{14} \text{ cm}^{-3}$
- c. Average plasma poloidal beta: $\beta = 10 \text{ to } 20\%$
- d. $n\tau_E \sim 10^{13} \text{ cm}^{-3} \text{ s}$

During the operations phase the objectives of the CPRF/ZTH research program are to extend and enhance the physics base of the RFP toroidal confinement configuration by demonstrating the principle of self-sustainment and high-beta operation in a compact configuration. CPRF/ZTH research results are expected to contribute in a major way to the physics of RFP toroidal confinement in the following areas:

- a. Study of high beta (10 to 20%), toroidal plasma parameter (β, n, T, τ_E), and ohmic heating dependences on toroidal current;
- b. Study of transport in the collisionless regime and the effect of field errors on confinement;

- c. Study of RFP formation, current ramping, F- θ control, and equilibrium control;
- d. Study of density control and termination control techniques;
- e. Study of edge plasma physics, impurity control, and wall protection techniques;
- f. Exploration of steady-state current drive using F- θ pumping or other helicity injection techniques;
- g. Study of technological issues and confinement physics at high-current, ignition-like temperatures, fusion relevant thermal wall loads, and significant d-d neutron flux.

The CPRF/ZTH will be designed to allow, after system modification, the installation of: pellet injectors, divertors, and helicity injection systems including F- θ pumping.

The objective of the CPRF/ZTH construction program is to design and construct a research facility with capabilities that satisfy the principal engineering requirements and performance expectations listed below:

- a. The CPRF shall have a 4-MA toroidal current capability with a 0.6 second experimental pulse (ramp and flat-top);
- b. The vacuum liner minor radius shall be 0.40 m with an aspect ratio of about 6;
- c. The ohmic heating coils, which drive the plasma discharge, must maximize electromagnetic energy transfer to the plasma consistent with minimizing field errors in the plasma volume and allowing good diagnostic and maintenance access to the torus;
- d. The equilibrium field coils, which provide a time-varying vertical field and field index to maintain plasma equilibrium, must minimize the required control power and asymmetric field errors in the

discharge chamber and allow good diagnostic and maintenance access to the torus, and;

e. The facility operating criteria are:

- (1) 10,000 4-MA discharges;
- (2) 20,000 2-MA discharges;
- (3) 50,000 1-MA discharges;
- (4) One 4 MA discharge per 10 minute period at the plasma design point conditions specified in the technical design criteria.

The CPRF will be powered by a generator with a rated output of 1,430 MVA, 600 MJ over a frequency range of 60 to 42 Hz. Power conversion equipment will be sufficient to supply the 4-MA RFP experiment. The generator will be installed to allow a later retrofit of a flywheel to provide an additional 1,400 MJ of usable energy.

The CPRF experimental hall has a floor area of 56 ft. x 190 ft. with a height of 33 ft to the 40 ton crane, and walls and roof of six foot thick concrete sufficient to shield d-d neutrons (2-5 MeV) and even the few 14 MeV neutrons that would result from a trace of tritium. A 30,000 ft² (approximate) power supply building will house the a.c. power distribution system, transformers, d.c. converters, controllers, capacitor banks, bus ducts, and other associated equipment. A pre-engineered metal building, with an area of approximately 11,000 ft² will provide a weather tight enclosure for the generator.

The engineering specifications for the CPRF/ZTH were drawn up by the Technical Steering Committee operating under the chairmanship of Dr. J. N. DiMarco. These specifications were determined by many factors, the most important of which are physics requirements, engineering constraints, available budget, and agreed-upon schedule.

The main purpose of the lecture delivered by the author was to describe in detail the physics rationale for the engineering specifications for CPRF/ZTH. This lecture drew material in a major way from the report by Dr. DiMarco on this subject written for the International Workshop on Engineering Design of Next Step RFP Devices held in Los Alamos, July 13-17, 1987. Instead of abstracting Dr. DiMarco's report here, it is provided as an appendix. - *DiMarco*

and cited separately. p. 50